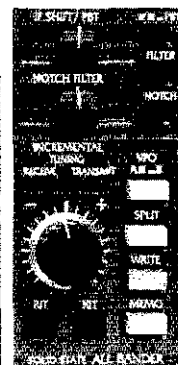
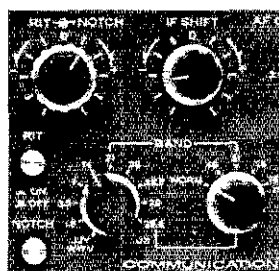
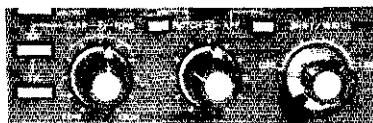




Receiver Features that Help You Beat Interference



Been plagued by "rotten QRM" lately? The right receiver features can help you copy the "weak ones."

By George Collins,* KC1V

What's the most important attribute of a modern receiver? Considering the crowded band conditions of today, most operators agree that the ability to copy signals in the presence of interference is at the top of the list. Modern receivers are provided with features to aid in this task — features that were not available a few years ago. Because most amateur stations are now equipped with a transceiver, our discussion of these features will center around the receiver section of a modern transceiver. Operation with a separate receiver differs in some ways, but much of this discussion also applies to "separates."

Crystal Filters

In one way or another, each feature we will be examining relates to *selectivity*. Basically, selectivity is the ability to reject interfering signals. In the past, receivers contained many stages of L-C (coil and capacitor) filtering to achieve high degrees of selectivity. This generally required multiple frequency conversions, which introduced problems with spurious responses and "birdies."

Selectivity in modern receivers is most often obtained through the use of crystal filters. Because these filters can be made for high frequencies (9 MHz is a common crystal-filter frequency), multiple conversions are not necessary. The crystal filter used in a receiver determines the basic selectivity. You can think of the filter as

the first line of defense against interference.

Bandwidth

Receiver selectivity is specified in terms of bandwidth. A bandwidth of 2400 Hz means that the receiver will respond to signals spread over a 2400-Hz range. This range is often referred to as the passband of the receiver. Normally, the receiver bandwidth specified is that of the crystal filter being used.

Many (but not all!) transceivers are provided with at least two crystal-filter bandwidths. A filter of approximately 2500-Hz bandwidth is standard for ssb reception. For cw reception, a filter of about 500-Hz bandwidth can be selected (the cw filter is often an option). Some transceivers do not have provisions for a cw crystal filter. Instead, cw selectivity is provided through the use of an audio filter. This is a less-expensive method, and it can be satisfactory for the casual cw operator. The limitations of audio cw filters will be discussed later when we look at audio filtering.

Several newer rigs are equipped with provisions for more than the basic ssb- and cw-bandwidth filters. Some also have a 1.8- or 1.7-kHz filter for ssb reception and a 300- or 250-Hz filter for cw operation. Using these additional filters lets you select the optimum degree of selectivity for a given mode and the current band conditions.

Shape Factor and Ultimate Attenuation

In addition to bandwidth, there are

other important filter specifications. One of these is the shape factor. It is the ratio of the filter bandwidth measured at a point of high attenuation on the filter response curve, to the bandwidth measured at a low-attenuation point (Fig. 1). Shape factor is a measure of the steepness of the filter skirts (or sides of the passband). Steeper skirts improve interference rejection and yield a *smaller* shape factor. Normally the -6 dB and the -60 dB response bandwidths are used to determine the shape factor.

Occasionally, however, the bandwidths at other points on the response curve are used for the calculation. Keep this in mind when comparing filter specifications, because the points chosen affect the value of the shape factor for a given filter. For example, if the -30 dB bandwidth is used for one filter and the -60 dB point is used for another, the two shape factors could have the same value, when in fact one filter has much steeper skirts.

Another critical filter parameter is ultimate attenuation. As you move away from the filter center frequency, you reach a point at which the attenuation no longer increases. At that point, the ultimate attenuation of the filter has been reached. The ultimate attenuation depends not only on the filter characteristics, but also on the way the filter is used. Poor circuit layout or improper filter placement can result in signals passing *around* the filter. Under such conditions, even the best filter will appear to have poor ultimate attenuation.

You can easily spot poor ultimate at-

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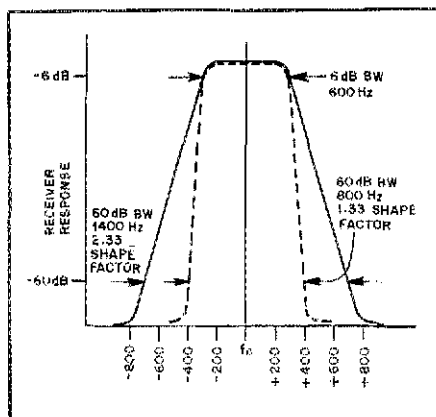


Fig. 1 — The shape factor of a crystal-filter passband is important to good receiver selectivity. A more rectangular passband provides better interference rejection and a smaller shape factor.

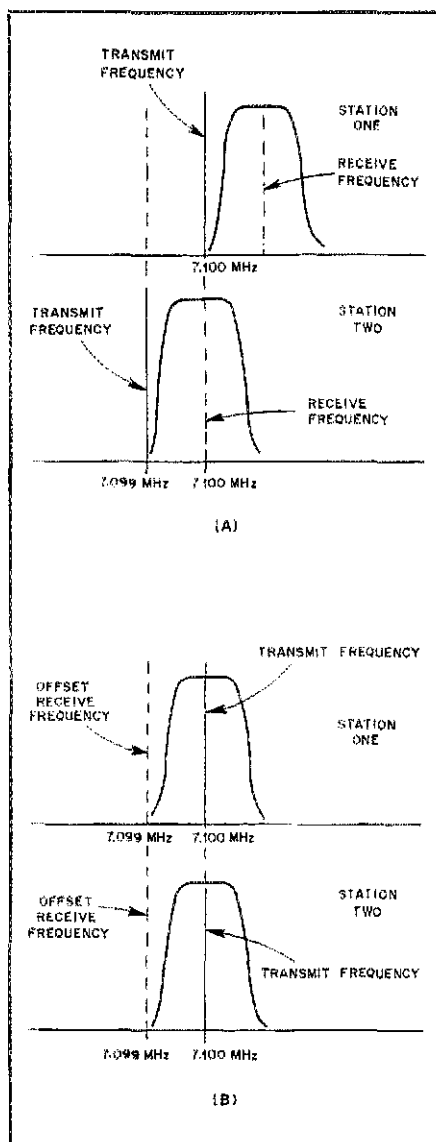


Fig. 2 — Without T-R offset, the transmit and receive frequencies differ by the audio beat note (A). Offset allows the transmitters to operate on the same frequency (B).

tenuation by tuning several kilohertz away from a strong signal. If you can still hear the signal (it will be high-pitched), the receiver suffers from leakage around the filter, or the filter has poor ultimate attenuation.

RIT and XIT

Receiver incremental tuning (RIT) has become an almost universal transceiver feature. While not changing the bandwidth, RIT helps you use the basic receiver selectivity to best advantage. RIT enables you to adjust the receive frequency without changing the transmit frequency. One important use of this feature is correcting for an operator who tunes to a beat-note frequency that differs from the transmit-receive frequency offset of his transceiver. In a transceiver, it is necessary to shift, or offset, the frequency when switching from transmit to receive. The amount of this shift is called the transmit-receive frequency offset, or offset for short. Without offset, tuning your transceiver to another station's cw signal would result in your transmitted signal falling outside the passband of the other station's receiver (Fig. 2A). You could call the other station all day this way and he would never know you were there! The solution to this problem is to offset the receive frequency of both transceivers. Now, by tuning your receiver to the other station's signal, your transmit signal automatically falls in his receiver passband (Fig. 2B).

Great — that fixes everything! Why do I need RIT?

Unfortunately, not all operators tune their receivers for a beat-note frequency equal to the offset frequency. If you adjust your transceiver tuning to obtain a desired beat note, it also causes your transmit frequency to change. Now the other operator must retune. This results in the stations "leap frogging" across the band. Having RIT enables you to avoid this situation. Once you have established contact with a station, don't use your main tuning control to adjust the pitch of the received signal. Instead, make any needed receive frequency adjustments with the RIT control. In a similar manner, RIT can be used to adjust the pitch of an ssb signal to your preference, without causing a change in your transmit frequency.

Some RIT controls will shift the receive frequency as much as 6 kHz. These controls can almost be used as a second VFO (variable-frequency oscillator), enabling you to work stations that are operating split (using different transmit and receive frequencies). DX stations often operate split to avoid having QRM on their transmit frequency cover their signal.

To set up your transceiver to work split, you first determine where the station you wish to contact is listening. Generally, this is easy, as you will hear others calling the

DX station on his listening frequency. With the RIT switched off, tune to that frequency. This places your transmitter on the correct frequency. Then turn on the RIT and use it to tune in the DX station. Most transceivers have an RIT switch that you can use to turn the RIT on and off without changing the control setting. This is very useful because it enables you to easily and quickly check your transmit frequency.

A control that is related to RIT is XIT (transmitter incremental tuning). It functions in a manner similar to that of RIT, but shifts the transmit rather than the receive frequency. When a transceiver is equipped with XIT, both the XIT and RIT shifts are set by the same control. Separate on/off switches are used to select the desired function.

A potentiometer is normally used as the frequency-shift control in RIT circuits. The potentiometer is part of a voltage divider used to supply a control voltage to a varactor diode. Varactor diodes act like voltage-controlled capacitors. By placing the varactor in the VFO tank circuit, the operating frequency can be varied by changing the potentiometer setting. To turn the RIT off (and during transmit periods), the variable voltage is removed and a stable, fixed voltage is applied to the diode.

XIT circuits are the same except that the variable voltage is applied during transmit and the fixed voltage is applied during receive. Switching of the variable and fixed voltages is done by means of transistor switches or relays. A simplified RIT/XIT circuit is shown in Fig. 3.

I-F Shift

This useful receiver feature is called *passband tuning* by some manufacturers. To make things even more confusing, the term passband tuning is applied to a completely different control by others. To avoid confusion, we'll use the term *i-f shift* for the control we're discussing now. Under either name, the principle (and result) is the same.

By changing the effective center frequency of the receiver passband, without changing the frequency to which the receiver is tuned, i-f shift allows you to make maximum use of the receiver selectivity. A typical amateur receiver will have a cw bandwidth of 500 or 600 Hz. While this is fairly narrow, it is possible to have two (or more) cw signals fall within the passband.

This situation is shown in Fig. 4A. Here the desired signal has been tuned to the passband center frequency (f_0). The interfering signal, 300 Hz lower in frequency, is also in the passband. By using your i-f shift control, you can "move" the passband center frequency as shown in Fig. 4B. Now the interfering signal is outside the passband, where it can be removed by the filter.

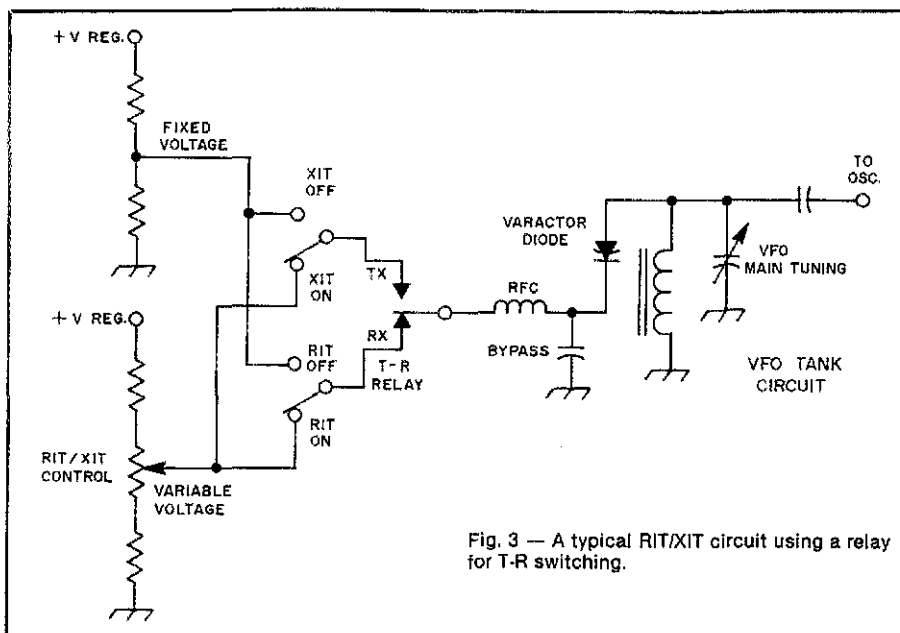


Fig. 3 — A typical RIT/XIT circuit using a relay for T-R switching.

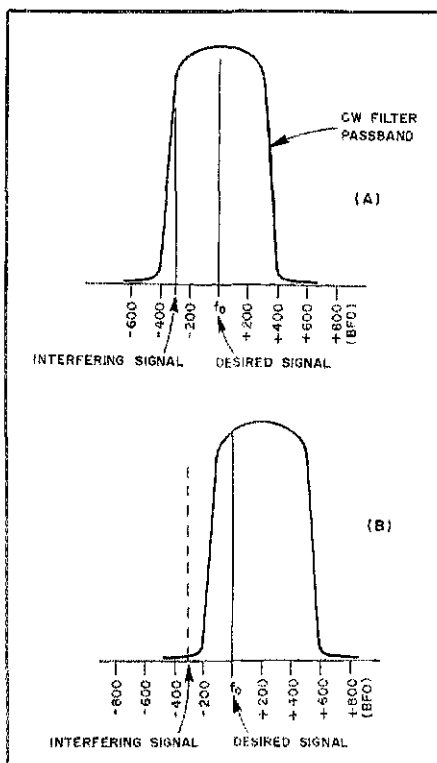


Fig. 4 — Interference from an undesired signal falling in the receiver passband (A) can be reduced by using the i-f shift control (B).

Note that this has been accomplished without adjusting the receiver tuning; thus, the pitch of the desired signal will remain the same. This is because the beat-note pitch, or frequency, is determined by the spacing between the signal frequency (f_o in this example) and the BFO (beat-frequency oscillator) frequency. In Fig. 4, the BFO frequency is 800 Hz away from the signal frequency; thus, the signal will

produce an 800-Hz audio tone in the receiver speaker.

Why not just tune the receiver to move the interfering signal out of the passband and listen to a different beat note? That is a possibility, but the problem is that with a transceiver as you tune the receiver you also change the transmit frequency. It is possible to compensate for this by using the RIT control.

If you're receiving an ssb signal, you don't have the option of changing the receiver tuning to move an interfering signal out of the passband. When you're copying ssb signals, the signal frequency and the BFO frequency *must* have the proper relationship (unless you enjoy listening to Donald Duck!).

Before we examine the use of i-f shift while receiving voice signals, let's review some ssb basics. In the process of amplitude modulating a carrier signal, two sidebands are produced. One sideband is above the carrier frequency, and the other is below the carrier. In an ssb transmitter, one of the sidebands is removed, generally by filtering, and the carrier is suppressed. The resulting signal is shown graphically in Fig. 5. When you tune in an ssb signal, two things must be accomplished. First, the received signal must be positioned correctly within the receiver passband. The second requirement is that the signal and BFO frequencies have the correct relationship. If the signal is to be reproduced properly, the BFO frequency and the suppressed carrier frequency (after conversion to the receiver i-f) must be the same (Fig. 6). If they're not, you'll hear the characteristic "Donald Duck" sound of an improperly tuned sideband signal.

Now let's see how i-f shift can be used to reject interference while receiving ssb signals. If you are listening to a signal and

another station begins transmitting on the *same* frequency, i-f shift won't save the day (nothing else will, either!). Fortunately, this type of interference is not the most common. More often, the interfering signal will be off to one side or the other, but close enough to overlap the desired signal. Such a situation is shown in Fig. 7A. You can see that a fairly large part of the interfering signal falls within the receiver passband. We can't change the receiver tuning to reduce the interference because that would move the desired signal away from the BFO frequency.

What can we do? Shift the passband! By using the i-f shift we can place the passband edge, or skirt, between the two signals (Fig. 7B). This can reduce the interfering effect of the undesired signal greatly. Shifting the passband will also cause part of the desired signal to be attenuated. The result is a reduction (in this example) of the higher voice frequencies. As long as we don't shift the passband too far, the voice will still be understandable. This puts a limit on how close the interfering signal can be and still be rejected. Naturally, if the interfering signal were lower in frequency than the desired signal, we would shift the passband in the opposite direction. In that case, we would lose some of the lower voice frequencies of the desired signal.

Earlier, we mentioned that the i-f shift and the RIT controls can be used together. The cw operator may find this useful to avoid the monotony of listening to the same beat note for long periods of time. Fig. 8A shows a "normal" tuning condition (no i-f shift or RIT): The signal is tuned to f_o , 800 Hz from the BFO frequency, and the passband is centered over the signal. If you prefer a lower-pitched beat note, the RIT control is used to tune the signal to the lower pitch. Then the i-f shift is used to reposition the passband center at the signal frequency (Fig. 8B). If you are using a fixed-frequency audio filter, you may want to use this technique to obtain peak receiver response at the af filter peak frequency. I-f shift can also be used to enable you to copy the standard RTTY (radioteletype) audio tones of 2295 and 2125 Hz while using a 500-Hz cw filter. Without i-f shift, these tones would be outside the cw passband.

How's It Done?

You can look at i-f shift as though it were changing the center frequency of the receiver i-f filter. Of course, it is not practical to make a variable-frequency crystal filter, so a mixing process is used to achieve the same result. In this process (Fig. 9), two mixers are used. Both receive a local-oscillator signal from the same variable-frequency oscillator. In the first mixer, the signal is converted from the i-f (455 kHz in this example) to the crystal-filter frequency. After passing through the filter, the signal is applied to the

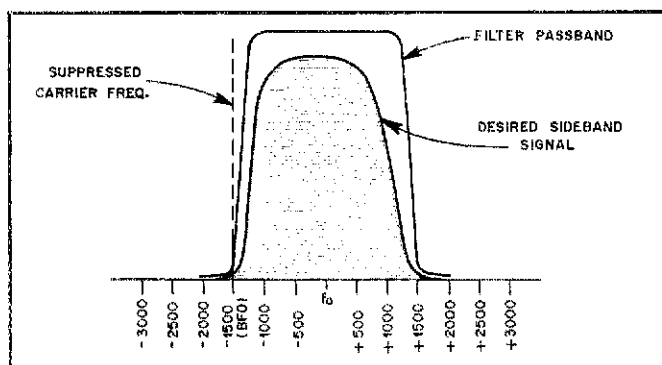
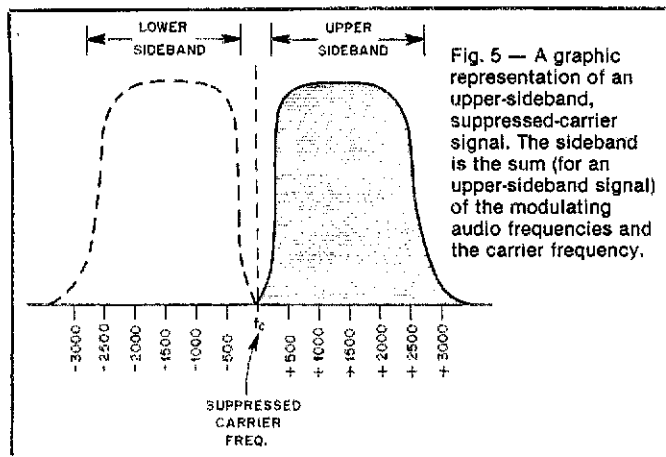


Fig. 6 — When tuned correctly, the sideband is centered within the passband, and the suppressed carrier and the BFO frequencies are aligned.

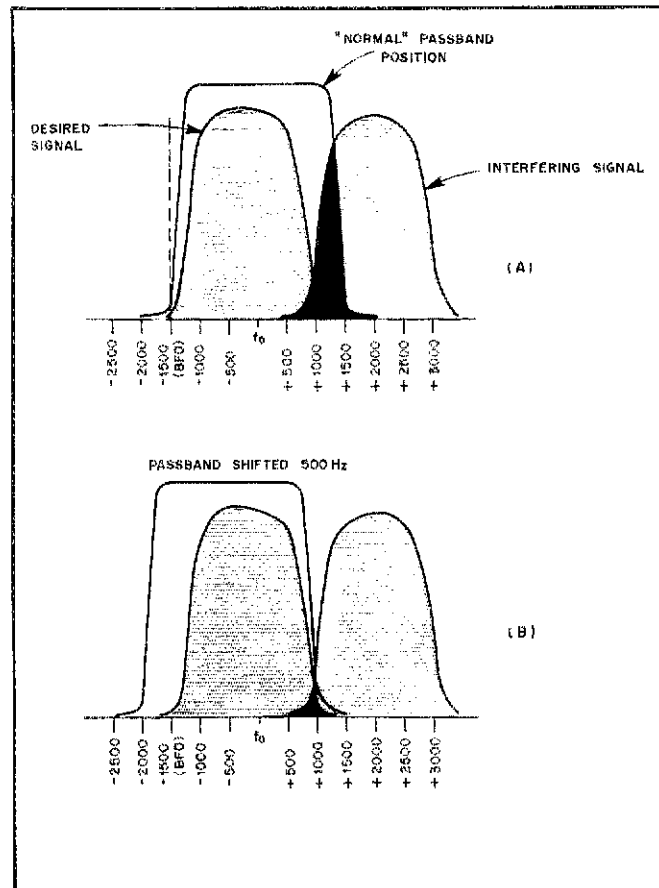


Fig. 7 — By shifting the passband, you can reject an interfering signal without disturbing the carrier and BFO frequency relationship.

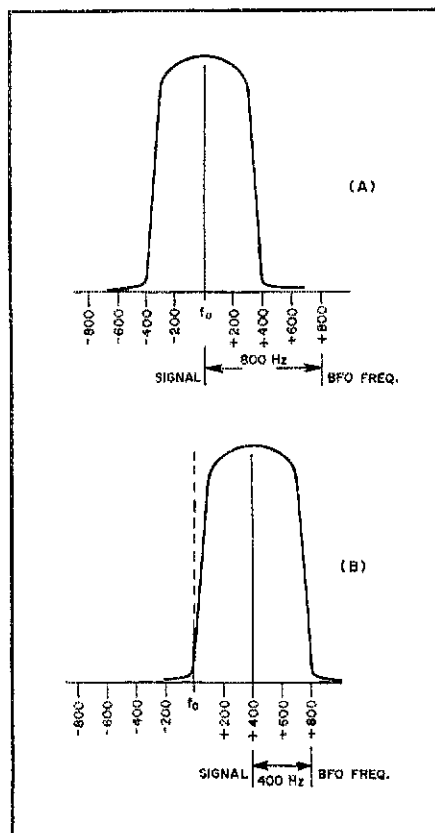


Fig. 8 — Using i-f shift and RIT allows you to select a different beat-note frequency without affecting the transmit frequency.

second mixer. Here it is converted back to the receiver i-f. If we change the oscillator frequency slightly, the input frequency (f_{sig}) that is converted to the filter center frequency also changes. The second mixer simply puts the filtered signal back where we started. The result is that we can select the frequencies that will pass through the filter without changing the receiver tuning.

As useful as i-f shift is, it is not a "QRM cure-all." We mentioned one limitation already: If the interfering signal is too close to the desired signal, i-f shift isn't going to be much help. Should there be two interfering signals, one above and one below the desired signal, i-f shift will

again be ineffective in producing Q5 copy. In this situation, the only way out is to reduce the width of the passband. For example, a 1.8-kHz filter could be used for ssb reception under difficult conditions.

Variable-Bandwidth Tuning

To avoid the expense of equipping a receiver with a multitude of crystal filters, *variable-bandwidth tuning* (VBT) circuits have been developed. These circuits allow you to adjust the receiver bandwidth to fit the operating conditions.

One way of implementing VBT is to place a second filter at the output of the i-f shift circuit (Fig. 10). We now have two passbands through which the signal must

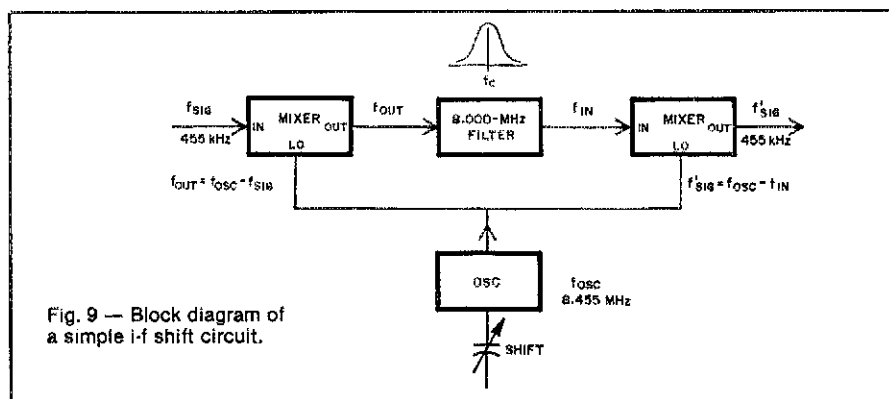


Fig. 9 — Block diagram of a simple i-f shift circuit.

pass. The first passband (that of FL1) can be "shifted" as we saw in our discussion of i-f shift. The second passband (FL2) is fixed. By adjusting the first passband so it is aligned with the second, we obtain the normal (maximum) bandwidth (Fig. 11A). If we shift the first passband, the overall bandwidth is reduced (Fig. 11B).

The maximum bandwidth obtainable with VBT is that of the narrowest filter in the system. If, for example, both filters have 2.7-kHz bandwidths, the maximum bandwidth will also be 2.7 kHz. Typically, the minimum usable bandwidth will be 100 to 300 Hz; it depends on the filters used and the design of the particular VBT circuit. Generally, cw filters will yield narrower minimum bandwidths than ssb filters. VBT is often used to achieve reasonable cw selectivity when a receiver is equipped only with ssb filters. This may prove to be very satisfactory for the operator who works cw only occasionally. When you are comparing features on different transceivers, be sure to keep in mind that VBT is called passband tuning on some rigs. If you have any doubt about the function of a control, check the owner's manual.

Notch Filtering

Another way of reducing interference is to "notch" the offending signal. A notch control, or filter, allows you to reduce the receiver response over a narrow band of frequencies. The notch frequency is adjustable, so you can tune it to the interfering signal. It is important that the notch be narrow; if it is too wide, it will reduce the desired signal amplitude along with that of the interfering signal.

Because the notch must be narrow, these filters are most effective in eliminating interference from signals of narrow bandwidths. A cw signal and the carrier of an a-m voice signal are examples of narrow bandwidth signals that can be handled by notch filtering.

Today, two types of notch filters are found in amateur transceivers. One type is the i-f notch. As the name implies, these filters operate at the receiver i-f. The other type is the audio notch filter. I-f notch filters are most often employed at relatively low frequencies, such as 455 kHz or 50 kHz. This is because it is easier to obtain the high circuit Q required for a narrow notch bandwidth at these frequencies. In single-conversion receivers, with an i-f in the 8- to 10-MHz range, notch filtering is generally provided by means of audio filters.

Both types of filters can be effective, although some audio notch filters do not provide as much attenuation, or "notch depth," as is afforded by a typical i-f notch filter. Typical values of attenuation range from 30 to 60 dB. If a filter has only a 30-dB notch, it will attenuate a 20-dB-over-S9 signal to a level equivalent to about S7. A 60-dB notch would reduce the same signal to approximately S2.

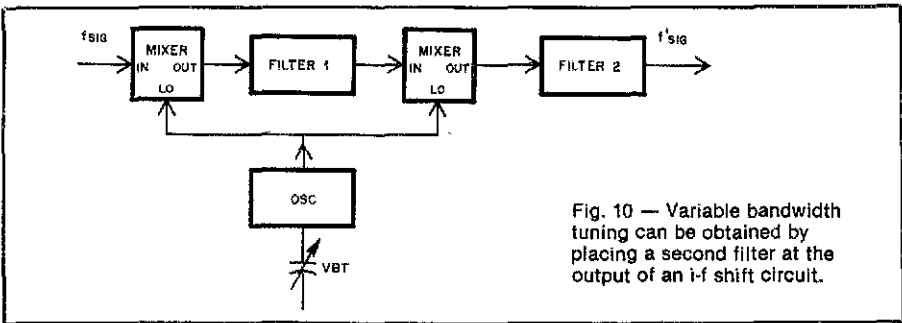


Fig. 10 — Variable bandwidth tuning can be obtained by placing a second filter at the output of an i-f shift circuit.

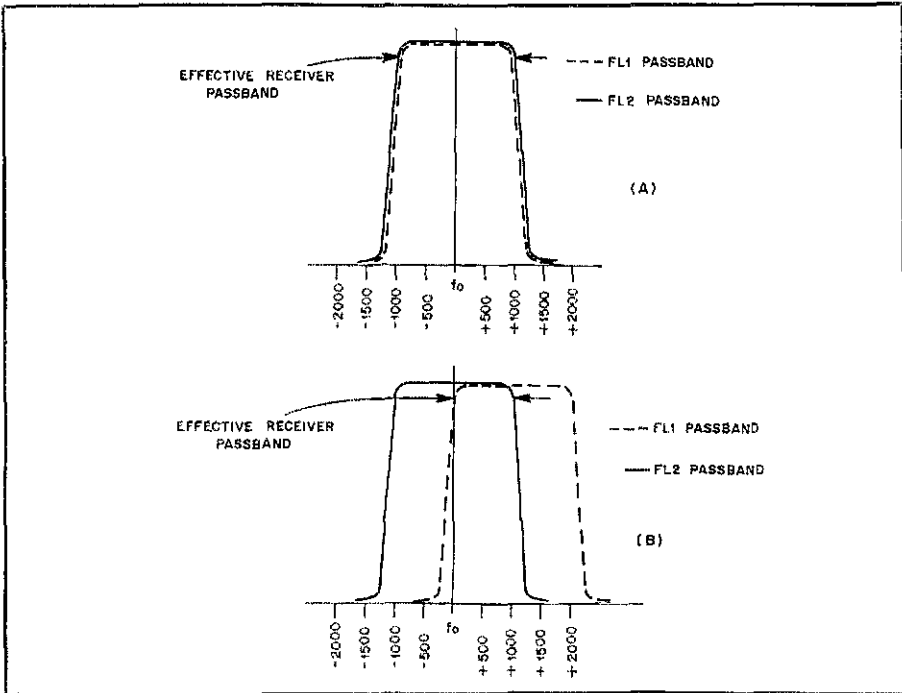


Fig. 11 — Variable bandwidth tuning requires the use of two passbands. By moving the center frequency of one passband, the overall bandwidth is reduced.

Audio Peak Filters

An af notch filter is one type of audio filter. Another type found in some receivers is the audio "peak filter" (APF). These filters are narrow-bandwidth band-pass filters. Usually, the bandwidth is a few hundred hertz (or less) and the center frequency is adjustable.

An APF can offer a significant improvement in overall selectivity, even in a receiver equipped with a narrow-bandwidth i-f filter. There are some drawbacks, however, when an APF is used in place of an i-f crystal filter for cw reception. Because the APF is located in the receiver audio section, a strong signal *outside* the APF passband can still be amplified to a very high level in the receiver i-f stages. In fact, the signal level can be so great that some receiver stages will be overloaded. Overload can produce distortion and a reduction in receiver sensitivity, making it impossible to copy the desired signal. A crystal i-f filter avoids this problem by removing the undesired signal before it reaches the i-f amplifiers. Even if the receiver is not

overloaded, the undesired signal can activate the agc (automatic gain control) circuit, reducing the receiver sensitivity to the point at which a weak signal can't be heard. Sometimes this problem can be overcome by switching to manual gain control.

Closing Comments

Well, these features are all very nice, but I don't need *all* of them, do I? Probably not. Okay; which ones do I need? That's a question each of us must answer for ourselves. Our personal operating styles and preferences will have a lot to do with what we require in a rig. If you're considering purchasing a new rig, think about the features your present equipment doesn't have the next time you operate. Would RIT or a notch filter help you out? If so, look for those features when examining a prospective new rig. If you are looking for your first rig, understanding what the various transceiver controls do (and don't do) should help when you make your choice.